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REPORT ON WESTERN PINE BEETLE STUDIES OF 1927 - CASCADEL UNIT, NORTHFORK, CALIFORNIA

By

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Hubert L. Person, Assistant Entomologist

INTRODUCTION

A number of the western pine beetle studies started on the Cascadel unit in 1925 and 1926 were continued through 1927. The description of the area, the details of the experiments and the results obtained up to spring of 1927 were given in the "Report on Western Pine Beetle Studies, Cascadel Unit, Northfork, California", dated March 14, 1927. As a result of the 1927 studies, it was found that there were sufficient data on two of the projects to warrant separate reports on them. In one of these the results of our work to date on the beneficial insects are given in "A Study of the Clerid, Thanasimus nigriventris, Lec., With Notes on Other Insect Enemies of the Western Pine Barkbeetle", dated May 8, 1928. The sample plot studies on tree selection by the western pine bark beetle are also to be worked up into a separate report.

This leaves, principally, the studies on tree resistance and attraction and the dendrograph record of diameter changes in beetle killed trees to be covered in this report. Another cruise of the Cascadel unit, made in the fall of 1927, enables us to include, as well, the course of the infestation on this area by seasons from the summer generation losses of 1924 to the winter losses of 1927.

Since, as noted, the 1927 report gives most of the details of the experiments, this report will be limited to a statement of the progress during 1927 on the studies not separately reported. It was found in 1926 that the results were not as definite as they might have been if the infestation on the area had been greater. This same difficulty was found in 1927 and will probably always be found in an area such as the Cascadel unit where heavy epidemic conditions probably never occur. Because of this it was decided to discontinue the work at Cascadel and transfer the field base for the western pine beetle studies to the northern Warner district of the Modoc National Forest.

TREE RESISTANCE TO D. BREVICOMIS ATTACKS

The object of this experiment is to compare the resistance to attack of different western yellow pine trees.

The method used was to cage the base of trees of different vigor, and other characteristics, start attacks by forcing the beetles to attack the caged portion of the trees and then to compare the action of the beetles and the effect on the different trees.

It was found from the previous studies, that:

1. Attacks by *D. brevicomis* may be started artificially on western yellow pine trees with the use of cages.
2. These attacks often start an attraction that results in a complete attack and the death of the tree.
3. In general, the trees vary in their resistance with the growth rate of the trees. Fast growing trees offer the most resistance, slow growing trees the least.
4. Certain western yellow pine trees are especially resistant to *D.brevicomis* attacks.

1927 Studies - First Generation Trees.

During the first flight period 5 caged trees were used in the resistance and attraction studies. Two of the trees, numbered 8 and 27, had been caged in 1926. Number 8 had been caged early in 1926 and a total of 17,200 newly emerged beetles from rearing cages had been introduced during the first and second flight periods but the tree had not been killed. Number 27 had been caged in July, 1926, and a total of 3,500 beetles had been introduced between August 15 and September 10.

The other three trees were healthy trees which had never been caged or attacked. The description of the trees is given in Table 1.

Details of Treatment of Caged Trees.

Tree K1-I. This tree was selected as an example of a healthy, vigorous tree which should be quite resistant to attack. See Photos 1 and 2.

Twenty feet of the base of this tree was caged and 312 square feet of bark was stacked inside, about the trunk. The emergence from this bark, based on a count of 10 square feet was estimated to be 46,000. This great excess of beetles resulted in an extremely heavy attack, about 150 to 200 beetles to the square foot and the tree was killed in spite of the fact that only a few attacks were made above the cage, none of which were successful.

The great resistance of this tree is evident when compared to K2-I, See Tables 1 and 2. Tree K1 had nearly 8 times as many beetles released in the cage, and 4 times as many attacks per square foot and yet it did not succumb until more than three weeks later than tree K2. Its unattractiveness to beetles in flight is also shown by the few attacks made above the cage. Later in the season the upper part of the trunk was attacked by <u>D.brevicomis</u> and <u>Ips</u> <u>confusus.</u>

<u>Tree K2.</u> This tree was selected as representative of a medium sized mature tree of medium slow growth rate. No bark was put in the cage, the <u>D.brevicomis</u> adults being introduced from rearing cages. Altogether 8,200 beetles were put in the cage but there was a complete attack both inside and outside of the cage and the tree was dead after only 4,500 beetles had been introduced.

<u>Tree No. 8.</u> Attempts were made to kill this tree during 1926 during the first, second and third flight periods, by putting in only the <u>D.brevicomis</u> adults collected from rearing cages. A total of 17,200 beetles were put in the cage in 1926 and yet the tree was not killed. In 1927, 253 square feet of bark was put in this cage from which 27,500 <u>D.brevicomis</u> emerged. Besides this enough <u>D.brevicomis</u> were introduced from the rearing cages to make a total of 64,700 beetles put in this cage during 1927. In spite of the enormous number of beetles caged with this tree, it did not succumb until June 21. In these experiments a tree is not considered dead until all resistance to attack from pitch flow stops on all sides of the tree. This usually occurs at about the time that the first egg laying begins. In some cases the pitch flow continued above the cage where only a few attacks were made, after it had stopped inside the cage. In these cases the tree was considered dead when there was a wide strip completely around the tree in which no resistance to attack resulted from the flow of pitch.

It is very difficult to explain why a tree of medium small size and medium slow growth rate should be as difficult to overcome as this tree was. See Photo 3. Two hypotheses might be offered: 1. Certain trees are peculiarly resistant to attack regardless of their growth rate or morphological character. 2. The resistance of a tree may be gradually built up by moderate numbers of unsuccessful attacks which have a tendency to increase the production of oleoresin by the attacked trees. During the first attack period of 1926 the beetles were introduced in such small numbers and in such a crippled condition (many of them had legs and antennae chewed off while being transferred from the rearing cages, due to poor technique) that they were unable to do more than stimulate the production of oleoresin. This was continued through the summer when there were not enough beetles in flight to aid the caged beetles by attacking the upper part of the tree. This continued, weak attack was sufficient to stimulate the oleoresin flow without weakening the tree so that by 1927 when a really adequate number of beetles were put in the cage the tree had become repellent to the beetles because of the large amount of pitch which covered the caged part of the trunk. This would indicate that the total number of beetles attacking is not as important as the degree of concentration of the attack. Trees may be "tapped" for years for turpentine without serious ill effects, but severe tapping will kill a tree in a very short time. It has been found that tapped trees produce much more oleoresin the second year than the first and it is reasonable to suppose that trees unsuccessfully attacked, if not seriously weakened, would be more repellent to D.brevicomis than the same trees before being attacked.

Tree K27. This tree was caged in July, 1926, and 3,500 D.brevicomis adults were introduced. See Photo 4. The beetles were put in too late to attract beetles during the second flight period and no beetles were attracted to the trees. Only about 200 attacks were made inside the cage.

In 1927, 265 square feet of infested bark was put in the cage. About 40,000 D.brevicomis emerged from this bark. A very heavy attack was made inside the cage and the tree was killed but only a few attacks were made above the cage.

The resistance and unattractiveness of this tree seems to disprove our theories since this is the slowest growing of all the trees caged. The only explanation of this inconsistency is that this tree, as in the case of tree 8, became unattractive and resistant as a result of the unsuccessful attacks of 1926,

1927 Studies. Second Generation Trees.

For the second flight 4 healthy trees, with no previous attacks, were caged. For the description of these trees see Table 1. In cage K1-II the infested bark was used but in the other cages only the D.brevicomis adults were put in the cages.

K1-II. This was a vigorous tree of good size and fairly fast growth rate. See Photos 5 and 6. A 20 foot cage was built around the base on July 8 and 335 square feet of infested bark was put in. About 36,500 D.brevicomis emerged. The emergence began almost as soon as the bark was put in the cage and the heavy attack inside of the cage attracted beetles in flight which attacked the uncaged part of the tree so that the tree was killed by July 20, just nine days after the first attacks inside the cage. The quick killing of this tree can probably be explained by the very heavy emergence of beetles from the caged bark within a short time and by the fact that there were evidently many beetles in flight in the vicinity to attack the exposed part of the trunk.

K2-II. This was a slow growing tree of medium size and with very thin bark. It was caged and killed by introducing D.brevicomis adults from the rearing cages. The first beetles were put in on July 12 and the tree was killed in one week, on July 19. As expected, this tree showed little resistance to attack. Only a few small pitch tubes were formed. The attack inside the cage attracted beetles in flight so that the entire trunk was well attacked.

K3-II. This tree was used primarily for the clerid studies. A new type of cage was used, by which 15 feet of the base of the trunk was divided longitudinally and caged separately. A total of 4,000 beetles was released in each side of this cage. The first beetles were put in the cage on July 11, and a full attack was secured both inside and above the cage and the tree was overcome on July 18.

K4-II. A new type of cage was used on this tree also, though somewhat different from the one used on K3-II. It was built as follows: first, two 16-foot lengths of 18 mesh 4-foot screen were fastened together lengthwise, with two wood strips, 1/2 inch by 4 inches, so as to make a 16 foot length, 8 feet in width. The bark was then smoothed on one side of the tree to be caged so that a 15-foot length of 2x4 could be nailed tightly to the trunk. The screen was then placed around the tree and the free edges were nailed tightly to this 2x4 with wood strips.

Strips of cotton batting were then fastened around the trunk just above and below the ends of the 2x4 and the screen was fitted tightly over this cotton so as to make a beetle tight cage. See Photo 7. This type of cage is much more easily constructed than the square type of cage, used formerly, and requires only one-half as much screen and about one-fifth as much 2x4 material. Its use is more limited because there is much less room inside the cage and it is impossible to make bark counts and examinations of the caged part of the tree until the cage is removed.

A total of 6,000 beetles were released in this cage (K4-II) but only a strip on one side of the tree was killed. The rest of the tree remained green and is still alive. The failure to kill this tree was probably due both to the small number of D.brevicomis used and the fact that the attack was started too late to attract beetles during the second flight period as well as to the fact that it is a fairly fast growing tree.

No trees were caged during the third flight period.

Discussion.

A summary of the essential data on each of the caged trees used in this study is given in Tables 1 and 2.

It is apparent that it is very difficult to reach any conclusions in a study of this kind because of the great number of variables and the limitations on the number of trees that can be used. This difficulty is particularly evident where the amount of infestation is limited as it is at Cascadel. Even if the time and money were available for caging an adequate number of trees it would be impossible to collect enough beetles on this area to start attacks on a large number of trees. With the new type of cage permitting the use of two or three times as many trees and with the heavy infestations found on the Modoc it is hoped that something more definite can be accomplished on the problem during the next few years.

Conclusions.

In spite of the inadequacy of the data for drawing definite conclusions, a number of interesting points are brought out by a study of the material presented in Tables 1 and 2.

1. The resistance of tree K1-I, a very vigorous tree, is quite evident and contrasts very strongly with the lack of resistance of K2-I which was attacked at about the same time.

2. Since tree K1-I was one of the most vigorous trees in that immediate vicinity and since it was killed by forcing the D. brevicomis to attack inside the cage, without any assistance from beetles in flight, it is probable that practically any western yellow pine can be killed in this way if enough of the trunk is caged and enough beetles are released inside the cage. It is essential that the cage be tight enough to prevent the escape of many of the beetles.

3. It seems quite remarkable that four of the trees, K1-I, 8, 27 and K3-I, to be described later, were killed from the attacks inside the cage with little or no aid from beetles in flight. This indicates lack of attraction or a lack of beetles or probably both.

4. The ease with which caged trees were killed by transferring the D. brevicomis adults from the rearing cages is also rather remarkable when we consider the failure of similar attempts in 1926.

K2-I was killed in this way with only 4,500 beetles introduced up to the time the tree was overcome.

Trees K2-II and K3-II were also killed in this way with a comparatively small number of beetles.

This method would probably be unsuccessful unless the uncaged part of the trunk was attacked by beetles in flight so the attack inside the cage must be timed so as to attract beetles during the height of a flight period.

5. It is difficult to separate resistance and attraction in these experiments. Attractive trees are attacked above the cage, provided there are beetles in flight, and are killed much more easily than unattractive trees which must be killed by the caged beetles alone. Trees numbered 8 and 27 were small trees with less than average vigor and yet they were very hard to kill, probably because the trees were not attractive to beetles in flight so that the caged beetles had to kill them without outside help. This may also account, at least in part, for the ease with which K1-II was overcome when compared with K1-I.

6. The difference in the period between attack and the death of the tree for trees killed during the first flight period and trees killed during the second flight period, is very marked, an average of 42 days for the first and

only 8 days for the second. Most of this difference is undoubtedly due to the much colder weather in the spring which makes the beetles less active and even entirely inactive on the colder days during April and May and the fact that the attacks, on the first generation trees, were started in the cages before the regular flight period. Another cause for this difference may be that the trees are much less resistant during July and August, when the available moisture is low and the physiological processes are slower.

Table 1.

Data on trees used in tree resistance studies

	Diameter Inches	Height Feet	Tree Class		Growth 1922-26 Average	*D*.*b*.Emergence from Introduced Bark	*D*.*b*.from rearing cage	Total *D*.*b*. introduced	Number *D*.*b*. that attacked	*D*.*b*. Dead in cage	*D*.*b*.Accounted for	Number *D*.*b*.escaped	Number of days attacked to death
K1-I	26	130	Vigorous	3	2.74	46,300		46,300	15,000	6,000	21,000	25,000	52
K2-I	20	110	Medium Slow	4	.70		8,200	8,200	4,200	1,200	5,400	2,900	23
8-I	20	110	Medium	4	1.16	27,000	38,000	65,000					53
27-I	20	100	Slow	4	.28	34,000	4,500	38,500	6,000	4,000	10,000	28,500	40
K3-I	28	100	Medium	3		26,500		26,500	21,500	500	22,000	4,500	
K1-II	24	130	Vigorous	3	2.15	37,000		37,000					9
K2-II	18	90	Slow	4	.20		6,000	6,000					7
K3-II	22	120	Slow	4	.25		8,000	8,000	5,000	1,000	6,000	2,000	7
K4-II	22	120	Medium fast	3	1.80		6,000	6,000					

Table 2.

Tree resistance studies

	First D.b. in cage	First Attack Inside cage	First Attack - Above cage	Medium Attack	Tree Killed	Attacks In-side	Per square foot Above	Brood per square foot Inside cage	Brood per square foot - Above cage	Emergence Inside cage	Emergence - Above cage	Number of Days attacked to death
K1-I	Apr. 22	Apr. 26	May 17	May 18	June 17	100		282				52
K2-I	Apr. 26	Apr. 30	May 15	May 18	May 23	26	21	242	162	247	76	23
8-I	Apr. 28	Apr. 29	May 21	May 26	June 21							53
27-I	Apr. 30	May 2	May 17	May 18	June 10	43		116				40
K3-I	Apr. 23	Apr. 26	May 13	May 24	June 20	72	(26)	466	(59)	Average Generation I		42
K1-II	July 8	July 11	July 12	July 16	July 20	42	25	203	180			9
K2-II	July 12	July 13	July 18	July 19	July 20		23					7
K3-II	July 11	July 12	July 14	July 16	July 19	33	25	221	170	220	150	7
K4-II	July 18	July 19	July 21	July 25	Aug. 7	(Strip on 1 side only)				Tree still alive		
										Average Generation II		8

ATTRACTION STUDIES

These studies are a part of the general tree selection study. We already know that certain trees are selected by D.brevicomis for attack, and it is now desirable to know the characteristics of attractive and unattractive trees. The immediate object of these studies is to determine (1) the comparative attractiveness of different western yellow pine trees and on what characteristics this attraction depends and (2) the effectiveness of various methods in attracting beetles.

As already suggested, the lack of a heavy infestation has handicapped the work, since it is not always possible to decide whether the failure to attract beetles is due to a lack of attraction or to a lack of beetles.

1. Caged Tree Experiments.

The details of this study and some discussion of the results are given under Tree Resistance Studies. See Tables 1 and 2.

K1-I. The most vigorous tree caged during 1927, attracted very few if any beetles until after the caged beetles had killed the tree. The few early attacks above the cage may have been the result of leakage from the cage. After the tree had been killed both D.brevicomis and Ips confusus were attracted to the upper part of the trunk during the later part of the summer.

K2-I. A very slow growing tree, was apparently quite attractive to beetles in flight since it was heavily attacked above the cage soon after the attack was started inside the cage.

Trees 8 and 27 were decidedly unattractive during 1927 but this may have been as much the result of the unsuccessful attacks during 1926 at a time when there were few beetles in flight as to any native unattractiveness. But just comparing these two trees we find that 27, a much slower growing tree than 8, was much more easily and quickly killed.

K1-II does not support our tree attraction theories. It was a moderately fast growing tree, apparently quite healthy and vigorous and yet it attracted beetles in flight so that attacks were started outside the cage only a day later than inside. This is difficult to explain unless we find that all trees become more attractive during July and August. Since most of the trees are killed by D.brevicomis during the spring and fall attacks, attractiveness

during July and August would be least important. In any case we can compare the attractiveness of a tree with that of another tree only when attacked during the same period. And comparing K1-II with K2-II and K3-II, we find that the two latter trees, both of which were slow growing trees, were probably more attractive, since the trees were more quickly killed with only a fraction of the number of beetles used on K1-II.

Conclusions.

While the results of the caged tree experiments seem to be inconsistent from the attraction standpoint, this is probably due to the nature of the experiment. Because the number of trees which could be caged was limited it was necessary to use the same set of trees for a number of different purposes. The result was that some of the trees were not very well suited to some of the experiments.

Obviously, with the small number of cages used, as many factors as possible should be eliminated. It is fair then to compare only trees which were attacked at about the same time and which had the same previous treatment. Limiting the comparison in this way we find that in each case the less vigorous tree is more easily and quickly killed and probably more attractive than the faster growing tree with which it can be compared.

Referring again to Table 1 we find that K2-I was certainly more attractive than K1-I, 27-I was more attractive than 8-I and K2 and 3-II were more attractive than K1-II.

K3-I. Oat Mt. Attraction Experiment.

The tree K3-I was 28 inches in diameter and 100 feet in height. It had a large crown, thick bark and a medium rate of growth. It was not a very desirable tree for this experiment because it was not considered an attractive tree and it was used only because no more suitable tree could be found near the top of Oat Mountain.

All D.brevicomis infestation within a mile and a half of this tree was destroyed during April before any emergence had started. 14 feet of the base of the tree was caged with the regular 4 foot square cage and 260 square feet of infested bark was piled inside around the trunk. The estimated emergence from this bark, based on a count of 10 square feet, was 26,500 beetles. A successful attack was made on all of the caged part of the trunk and the tree was killed. Successful attacks were made for nearly 5 feet

above the cage all around the trunk and for 10 feet above the cage on the south side. A total of 283 attacks were counted above the cage. These attacks would account for probably 600 beetles.

The results of the experiment are not very definite. Because of the small number of attacks made above the cage it cannot be determined whether these attacks were made by beetles attracted from outside of the cleaned area or by beetles which escaped from the cage. The cage was made as tight as possible but there may have been some leakage. However, the small number of attacks made above the cage shows that this tree was not attractive enough to draw beetles in any great numbers to the upper part of the trunk, even after the caged part of the tree was well attacked.

2. Attraction Through Piling *D.brevicomis* Infested Bark at Base of Tree.

The object of this experiment was to find some method of starting an attack on a selected tree without the use of a cage; and also to determine the attractiveness of a small number of *D.brevicomis* attacks.

The method used was simply to pile approximately one hundred square feet of infested bark about the base of different western yellow pine trees. Care was taken to protect the bark from the direct rays of the sun.

Five trees were used in this experiment during 1927.

A summary of the important data on these trees is given in Table 3.

Table 3.

Tree Number	Bark Piled at Base	Diameter Inches	Height Feet	Growth Rate and Tree Class	Number of *D.b.* Attacks	*D.v.* Attacks	Remarks
KA34	Apr. 29	34	130	Medium Slow 4	40	15	All attacks unsuccessful and tree not killed.
KA35	Apr. 29	20	70	Slow 7	45	20	All *D.b.* attacks failed and tree not killed. 3 or 4 successful *D.v.* attacks.
KA36	Apr. 29	28	140	Medium 3	20	10	All attacks failed and tree not killed.
KA37	Apr. 29	28	110	Medium Slow 5	60	-	All attacks failed and tree not killed.
KA40	Apr. 29	22	110	Medium Slow 4	6/10-many att. 6/25-complete att.	10	Beetles in flight attracted and tree killed by June 25.

Results.

The results are similar to those of the 1926 studies in that 1 out of the 5 trees was killed by attracted beetles. In the 1926 experiments, however, the tree was not killed until the third generation attack although the infested bark was piled around the base during the first flight period.

In 1927 all of the five trees used were attacked, from 20 to 60 attacks on each of the trees which were not killed and thousands of attacks on tree KA40. The attacks made on the trees which were not killed were all made near, or within 5 feet and above where the infested bark was piled and undoubtedly resulted from the emergence from the infested bark. There was evidently no attraction of D.brevicomis in flight to any of the trees except to the one that was killed, KA40. D.valens is much more easily attracted in this way as all of the trees with the possible exception of KA37, were attacked near the base by D.valens.

There is evidently little or no relation between the number of attacks made on trees from infested bark piled at the base, and the growth rate or vigor of these trees. The tree that was killed, however, would have been considered a susceptible tree.

Both the 1926 and 1927 studies, and also the Jackson Experiment of 1923 and 1924 show a strong desire on the part of a very large per cent of the beetles to fly away from the place of emergence. Probably 10,000 beetles emerged from each pile of bark and of this number not more than 1 per cent attacked the tree at which the bark was piled, with the possible exception of those at tree KA40.

Conclusions.

It is evident from the above that:

1. Most of the beetles which emerge fly to some other tree to attack.

2. Little attraction results from the small number of attacks that are made.

3. This method cannot be depended upon for starting attacks in a selected tree at least where the infestation is in an endemic stage. This method may give better results where the infestation is heavier.

3. <u>The Attraction of Transferred Pitch Masses.</u>

The purpose of this experiment is to determine the attractiveness of fresh pitch tubes. Only two trees were used because of a lack of time and because of the small amount of infestation on the Cascadel area. This method of attracting <u>D.brevicomis</u> will be more thoroughly tested on the Modoc area during 1928.

<u>KPA-1.</u> This tree was 16 inches in diameter and 80 feet in height. It was a slow growing, partly suppressed tree in class 7.

On May 25, ten <u>D.brevicomis</u> pitch tubes from a newly attacked tree were placed in bark crevices around the trunk at from 3 to 5 feet above the base. They were carefully handled in order to have them appear and smell as natural as possible.

On May 27, twenty more pitch tubes were placed on the trunk in a similar manner. Up to June 1 no beetles had been attracted to the tree but on June 27 when the tree was next examined, a good attack by <u>D.brevicomis</u> was found and the tree was overcome. The first attacks were probably made about June 20.

Since the tree was a very slow growing, susceptible tree it might have been attacked even if the pitch tubes had not been placed on it. But the evidence indicates that the pitch tubes were attractive to beetles in flight.

<u>KPA-2.</u> This tree was also 16 inches in diameter, 80 feet in height and moderately slow growing.

On May 28, fifty fresh pitch tubes were smeared on the trunk of this tree. Evidently there was very little attraction from these pitch tubes as no attacks were made on this tree.

4. <u>The Attraction of Attacks Started in Nail Holes.</u>

The object of this experiment is to determine the attractiveness of a few <u>D.brevicomis</u> attacks started artificially.

Holes about 1/2 inch in depth were punched in the bark of selected trees and beetles started into these holes.

The experiment was started on May 16 when three slow growing trees were selected and a number of beetles were started into the nail holes.

KN. This tree is 24 inches in diameter and 115 feet in height. The chronological outline of the experiment is as follows:

May 16 - 20 new adults of both sexes were started into nail holes.
Only 1 pitch tube was formed by these 20 beetles.

May 23 - 10 female beetles were started into nail holes.
May 23 to 27 - 50 female beetles were started.

May 31 - 15 beetles of both sexes were started.

June 1 - 15 " " " " " "

Altogether only 14 attacks were started by the above 110 beetles. All of these attacks were unsuccessful and no beetles were attracted to the tree.

KN-1. This tree is 24 inches in diameter and 110 feet in height.

Between May 16 and 20, eighty beetles of both sexes were started into nail holes. Of this number 15 attacked and formed pitch tubes.

Between May 23 and 27, forty female D.brevicomis were started into nail holes. Twelve of the above attacked and formed pitch tubes. On may 31 and June 1, twenty-five D.brevicomis of both sexes were started. Only two of this group attacked.

All of the above attacks were unsuccessful and no beetles were attracted to the tree.

KN-2. This tree is 20 inches in diameter and 100 feet in height.

May 17 to 23, sixty D.brevicomis of both sexes were started into nail holes. Nineteen of the above attacked and 15 formed pitch tubes.

May 24 to 27 -fifty females were started into nail holes, of which number 12 attacked and 9 formed pitch tubes.

May 31 - ten D.brevicomis of both sexes were started into nail holes. Three of these attacked and 2 formed pitch tubes.

A summary of the results is given in the following table:

Table 4.

Tree Symbol	Number of D.brevicomis started: Mixed Sexes	Females	Total	Number of attacks started: Mixed Sexes Number	Mixed Sexes Percent of Total	Females Number	Females Percent of Total
KN-0	50	60	110	6		8	
KN-1	105	40	145	17		12	
KN-2	70	50	120	22		12	
Totals	225	150	375	45	20	32	21.5

20 per cent of the beetles in the mixes sex group attacked and 21.5 per cent of the females attacked. A total of 77 attacks was made and 60 pitch tubes were formed.

All of the attacks were unsuccessful and the attacking beetles were drowned out in from 1 to 8 days.

The small number of attacks, from 15 to 30 to a tree evidently resulted in no attraction to beetles in flight.

5. The Attraction of Ips-topkilled Trees.

The purpose of this study is to determine the attractiveness to D.brevicomis of western yellow pine trees which have been topkilled by engraver beetles. Most of the topkilling on the Cascadel area was done by Ips confusus.

A record has been kept of all trees, both topkilled and completely killed by D.brevicomis, on the Cascadel area since 1924. Each topkilled tree is marked so that the number of such trees that are subsequently killed by D.brevicomis can be determined.

The total number of trees, on the Cascadel area, which were topkilled in each of the three years 1924, 1925 and 1926, was determined and the number and percentage of these topkilled trees which were subsequently killed by D.brevicomis was then found.

Most of the topkilled trees which are subsequently killed by D.brevicomis are killed within one year after being topkilled.

The results for 1924 and 1925 were given in the 1927 report but they will be included here to show the results for three years on the Cascadel area.

Table 5.

Topkilled trees subsequently killed by D.brevicomis

Year of top-killing	Total Number of Topkilled trees	Topkilled trees killed by D.brevicomis 1925 to 1927 inclusive	
		Number	Per cent
1924	148	68	46
1925	12	2	17
1926	62	26	42
Totals	222	96	Average 42

The results are also shown graphically in Fig. 1.

This shows that topkilled trees are decidedly attractive to D.brevicomis. Whether this attraction is the result of the weakening of the tree or to something peculiar to the work of the Ips has not been determined.

It would be interesting to determine whether or not there is any relation between the amount of the crown killed and the degree of susceptibility.

This high degree of susceptibility to D.brevisomis attacks of topkilled trees increases the importance of engraver beetle work on timber sale areas, right-of-way clearings and other areas where careless handling of slash causes temporary outbreaks of Ips which result in the top-killing of many trees. If 25 to 50 per cent of the top-killed trees are to be killed by D.brevicomis more attention will have to be paid to the so-called secondary engraver beetles.

6. The Attraction of Artificially Top Pruned Trees.

The purpose of this experiment is to determine whether or not top pruning trees will make the trees as susceptible to attack as top killing by *Ips*.

It is hoped that this experiment will aid in determining the cause of the attractiveness of *Ips* topkilled trees. If this attractiveness is due to the weakening of the tree alone we should be able to make trees attractive by severe pruning.

Method.

Twenty trees were selected so as to give a fairly wide range of sites and tree classes and from 5 to 40 feet of the top was cut out of each of these trees. The essential data are given in the following table:

Table 6.

				Crown Length		
Tree Number	Diameter	Height (Bef. pruning)	Tree class	Before cutting	Length cut off	Length after cutting
	Inches	Feet		Feet	Feet	Feet
T 1	14	75	7	30	20	10
T 2	22	90	4	60	30	30
T 3	26	110	3	75	32	43
T 4	22	90	3	70	22	48
T 5	26	80	3	52	22	30
T 6	26	130	3	80	35	45
T 7	20	130	2	45	28	17
T 8	24	80	4	65	20	45
T 9	18	125	2	25	15	10
T10	20	130	3	80	20	60
T11	20	125	3	65	25	40
T12	22	80	7	10	5	5
T13	28	100	4	30	20	10
T14	18	80	7	30	15	15
T15	18	70	7	35	25	10
T16	26	80	4	40	25	15
T17	36	140	4	50	25	25
T18	18	110	2	55	30	25
T19	20	110	2	60	30	30
T20	22	110	1	75	40	35

The wide variations in both the amount and the percentage of the original crown that was cut off is noticeable. This was done to find out if there is any relation between the amount of crown cut off and the attractiveness of the tree after being "topped".

Results.

The trees were examined a number of times during 1927 and an examination was made on May 3, 1928.

No insect attacks of any kind were found on any of the trees.

Conclusions.

It is possible that some of the trees will be attacked during 1928 so it is too early to draw any definite conclusions.

It seems evident, however, that this type of "topping" does not affect the tree in the way that topkilling by insects does, since if these 20 trees had been topkilled by insects a year ago it is probable that 25 per cent of them would have been killed by D.brevicomis by now.

Since the effect on the physiology of the tree is not comparable in the two cases, it is reasonable to expect that the effect upon attractiveness would also be different.

The 20 "topped" trees at Cascadel should be examined at least once a year for the next two or three years and the effect of the "topping" on growth and attractiveness to D.brevicomis followed. It would also be desirable to top another set of trees on the Modoc area where the infestation is much heavier.

7. The Attraction of Burning Western Yellow Pine.

The studies by Miller and Patterson on the relation between insects and fire have shown that there is usually a marked increase in the D.brevicomis infestation of an area following a fire. In connection with the Northfork burn study of 1924 to 1927, Miller found that the insect loss was not very great until nearly a year after the fire and that the trees which were most severely defoliated and consequently the slowest to recover from the fire were the ones that suffered most from bark beetle attacks.

This indicated that the relation between fire and insects (D.brevicomis) is an indirect one. The beetles apparently are not attracted directly by the fire but instead they build up an infestation within the burned area because of the unusually large number of highly susceptible, fire-weakened trees. This might involve attraction from the surrounding area, because of the more favorable host material on the burn, as well as a breeding up on the burn itself.

The Cascadel experiment was outlined by Miller to check the attractiveness of burning western yellow pine to D.brevicomis .

Experiment 1.

Method.

A group of 9 western yellow pine, from 20 to 30 inches in diameter, was selected as being close to D.brevicomis infestation, advantageously situated for preventing spread of fire and composed of the right types of trees for the experiment. See Table 7 for description of trees and other data.

On April 29, 1927, a pile of dry brush 10 feet in height was burned in the center of this group of trees. The flames reached past the top of the highest tree in the group and all types of burn from I to V were secured. Table 7 also gives the amount and character of the burn for each tree.

Four of the trees, 21, 27, 28 and 29 received a class II fire injury, that is, less than 25 per cent foliage injury and very little cambium injury.

K26 received a class III fire injury with 50 per cent of the foliage killed and no cambium injury.

K25 received a class IV fire injury with 80 per cent of the foliage killed and no cambium injury.

K22, 23 and 24 received a class V fire injury with 90 to 100 per cent of the foliage killed and a small per cent of the cambium killed near the base.

The trees were examined on May 5, 13 and 25 and on July 13. When examined on July 13 no insects, with the exception of the one D.valens, had attacked the trees. As the trees were burned just before the height of the first flight period of D.brevicomis and were not attacked during either the first or second flight periods, there

was evidently no very strong attraction from the freshly burned trees. Only two of the trees, K23 and 24 were attacked and killed by D.brevicomis and these were not attacked until four and four and one half months after the fire, respectively. After such a long time any attractiveness of the fire would probably have disappeared so that only the weakening effect on the tree would remain to make the tree susceptible to attack.

Table 7.

Tree Number	Diameter Inches	Height Feet	Tree class	Date Burned	Fire Injury: Class	Fire Injury: Needle injury Per cent	Fire Injury: Cambium scorched	Insects: Species	Insects: Date
KB21	26	130	3	Apr. 29	II	15	Few spots near base	No insects	
22	30	125	5	"	V	90	Medium strip on SE side	D.v. one attack	May 13
23	22	110	2	"	V	100	Few spots near base	D.b.complete attack	Sept.1
24	22	105	2	"	V	100	No cambium injury	D.b.complete attack	Sept.20
25	28	140	3	"	IV	80	No cambium injury	No insects	
26	34	140	3	"	III	50	" "	" "	
27	20	100	2	"	II	20	" "	" "	
28	30	125	3	"	II	10	" "	" "	
29	26	130	3	"	II	None	Fire scar enlarged	" "	

This agrees with the conclusions from the Northfork burn study as does the fact that the two most severely burned trees were the ones selected by D.brevicomis.

This group of trees was examined again this spring and none of the other trees had been attacked. It would probably be worth while to examine these trees at least once a year for the next few years to determine the effect of the burn on the surviving trees and whether or not any of the other trees are attacked.

Experiment 2.

In this experiment small green western yellow pine trees and D.brevicomis infested bark were piled near susceptible trees and burned during the first flight period. The description of the trees and the details of the experiment are given in Table 8.

Table 8.

Tree Number	Diameter Inches	Height Feet	Tree Class	Material burned	Date	Remarks
KB30	34	150	3	Small green western yellow pine trees	4/29/27	No insects attracted.
				" " " " "	5/25/27	
KB31	22	90	6	" " " " "	4/29/27	No insects attracted.
				" " " " "	5/25/27	
KB32	20	120	7	Pile of small D.b. killed western yellow pine and D.b. infested bark	4/29/27	No insects attracted.

KB30 and 31 are two trees about 25 feet apart and the trunk, limbs and needles of small, green western yellow pine were piled and burned between the two. No insects were attracted. KB32 was one of a group of trees. The infested western yellow pine trunk and bark were piled and burned within a few feet of this tree so that the bark (of KB32) was scorched around the base. But no insects were attracted.

All of the burning was done just before or during the height of the first D.brevicomis flight period.

Conclusions.

The results of both of these experiments, too limited in themselves to prove anything, agree with our conclusions from other fire studies, namely, that burning western yellow pine trees, whether needles, limbs or bark do not attract D.brevicomis and that any increase in infestation on burned over areas is the result of a sudden increase in the number of highly susceptible trees due to defoliation or cambium injury by the fire.

8. The Attraction of Large Numbers of D.brevicomis Adults.

The purpose of this experiment was to determine whether or not the D.brevicomis adults themselves would be attractive to beetles in flight. Normally the female beetles make the first attacks and the males and other females are attracted until the stem of the tree is completely infested. It was thought that a part of this attraction might be due to the attraction of the beetles themselves, sexual or otherwise.

Two methods were used in this study.

Experiment A.

In connection with the caged tree experiments, two cages were used for collecting beetles as they emerged from infested bark. See Photo 8. Since there were as many as 8,000 to 10,000 D.brevicomis on the walls of the larger rearing cage and up to 5,000 on the walls of the other, at one time, it is believed that if there was an attraction between the beetles themselves, beetles in flight should have been attracted to these cages.

But although the cages were used through both the first and second flight periods and examined nearly every day there was little evidence of attraction to these cages. The few beetles found on the outside of the cages were almost always found near the seams used for opening and closing the cage, where some leakage was known to occur.

It is concluded from the above that large numbers of beetles in themselves are not very attractive to beetles in flight.

Experiment B.

In this experiment 1,000 D.brevicomis adults were crushed up and smeared in the bark crevices of a susceptible tree, and 1,000 were crushed and mixed with 4 ounces of western yellow pine oleoresin and spread about on the bark of another susceptible tree.

As no attacks were made by D.brevicomis on either of these trees there was no evidence that these crushed beetles were attractive to beetles in flight. The experiment was so limited that the results are little more than indicative but no evidence of attraction was found.

9. Attraction of a Girdled Tree.

In the fall of 1925 Miller tried to attract D.brevicomis by scoring trees in different ways. In one of these experiments he girdled a 16 inch young, vigorous western yellow pine by removing a 2 foot strip of bark and phloem completely around the tree at about 4 feet above the base. This girdling was done on July 6, 1925.

On July 9, 1926, this tree was examined by Miller and Person and found to be still alive and apparently in a fairly healthy condition. No insect attacks had been made on the tree. As a few narrow strips of phloem had been left and as they were being extended and healed over, the 2 foot strip was again, and very carefully, girdled down to the sapwood.

On October 8, 1927, when this tree was next examined, it had been killed by D.brevicomis and at that time contained a brood of one-half grown D.brevicomis larvae. Evidently the tree had been attacked some time early in September.

As this tree was a young, vigorous tree, fairly well isolated from other infestation, which would not ordinarily have been attacked, it appears that the bark girdle so weakened the tree that it became attractive to D.brevicomis.

Since the results of other girdling experiments by Patterson and others do not agree with this result, it is not safe to draw conclusions from a single tree. However, it would be desirable to continue this experiment on a larger scale to determine the attractiveness of girdled trees.

DENDROGRAPH STUDIES

The two dendrographs used during 1926 were also used in 1927.

Our purpose during 1927 was to check the 1926 results and also to get a natural growth curve for the season on a healthy western yellow pine. It is believed that a better understanding of the life processes of normal trees and how they react to different soil moisture and temperature conditions will help us in our studies of tree resistance and attraction. It is possible that the same tree varies greatly in its susceptibility and resistance to insect attack at different seasons of the year.

Both of the trees used, No. 8 and No. 8a were used as dendrograph trees in 1926. See Table 1 for the description of tree 8. Tree 8a is 20 inches in diameter and 110 feet in height. It is a young, fairly vigorous codominant tree of Class I.

The dendrographs were installed about May 1 and were adjusted and operating smoothly by May 5.

The method of treatment for tree 8 is given in Tables 1 and 2 and described under the tree resistance studies. Tree 8a was not attacked by insects or injured in any way.

Results.

The results are given in Fig. 2. The solid line shows the growth or shrinkage of the trunk. It is based on the smallest diameter of the trunk as recorded on Thursday of each week. The diurnal changes in diameter for the same days are shown in dotted lines.

Curve 1 is the diameter curve for tree 8a, the healthy tree. It shows a continuous gradual increase in diameter from May 5 to June 9, a slight decrease from June 9, to June 23, a quite rapid increase from June 23, to July 21, and then a flattening out of the curve with an indication of more growth beginning August 11. The diameter decrease from June 9, to June 23, is difficult to explain. We had some trouble with the instrument in that period which may account for this dip in the curve. The principal period of growth evidently occurred between June 23, and July 21. The fall growth period did not begin until about the middle of September in 1926 but it evidently began soon after the middle of August in 1927. It is unfortunate that trouble with the clock prevented us from getting a record through September.

Curve 2 shows the beginning of growth in tree 8 which continued even after a number of attacks had been made. Early in June a very heavy attack was made and the tree was killed. This resulted in a rapid drying out and consequent shrinkage of the phloem and the sapwood which continued at a decreasing rate up until the end of the season. As the tree became drier and the needles ceased to function the diurnal change in diameter became barely perceptible and the curve became almost a straight line. These results correspond with the 1926 results and with the results at Asheville so it hardly seems worth while to get more records from dying trees. It would be of value to check the growth periods of normal trees at our new location on the Modoc.

ANALYSIS OF THE INFESTATION ON THE CASCADEL UNIT

Course of D.brevicomis Infestation, 1924 to 1927.

A 100 per cent strip cruise of the Cascadel unit was made in October by Person and Wagner which gives us the complete loss on this unit from the summer loss of 1924 to and including the summer loss of 1927. Only a part of the 1927 winter loss was found. The results in number of trees are given in Fig. 3.

It is noticeable that in both cases the unusually heavy loss occurred during the summer generations. But since the summer loss includes two generations, both the first and second, it is reasonable to expect the summer loss to be greater than the over-wintering loss which includes only one generation, the third.

The loss by volume and number of trees for 1926 and 1927 is given in Table 9.

Table 9.

D.brevicomis Losses - 1926 and 1927 (partial)

	Number of trees	Volume
1926		
Summer	70	88,190
Winter	68	42,450
Total	138	130,640
1927		
Generation I	51	54,830
" II	62	75,870
Unclassified Summer	63	80,050
Total summer	176	210,750
Winter (incomplete)	14	11,060

Analysis of Infestation.

When the area was cruised all dead trees were marked and recorded regardless of what caused their death so that it is possible to give the total loss on the area distributed according to the primary cause. In some cases, it is difficult to determine the cause of the death of a tree because a number of factors may have contributed.

As shown in Table 10 the total 1927 loss on the Cascadel unit was apparently caused by insects. Some windfalls may have been missed. There were no fires on the area and no lightning killed trees. It is possible that some of the trees classed as insect killed may have been seriously weakened by drought, fungus or some other agency but this could not be determined without detailed study.

Table 10.

	Number of Trees		Volume	
	Number	Per cent of total	Board Feet	Per cent of total
D.brevicomis	190	86.5	221,810	84.4
Ips confusus	21	9.5	25,920	9.8
Melanophila (gentilis?)	5	2.3	1,580	.6
D.monticolae	4	1.7	13,640	5.2
Total	220	100.0	262,950	100.0

While D.brevicomis is by far the most important tree killing insect on the area, an analysis of the stems of a number of the infested trees which were felled shows that probably not over 60 per cent of the bark area of the D.brevicomis killed trees was infested with D.brevicomis. It was found in the cage experiments that D.brevicomis could kill a tree by a concentrated attack on the basal 15 to 20 feet of the trunk and naturally attacked trees are often found which were evidently killed by a heavy attack on only the central part of the trunk.

In Fig. 4, which was taken from Struble's report on D.valens, the distribution of the different important insect species is shown graphically for five trees.

It was found that although only a part of the total bark area was occupied by D.brevicomis this species was almost always the immediate cause of the death of the tree. Referring to Fig. 4 again, tree J138 was killed in 1926 and except for 10 feet of the top and a couple of feet at the base, the entire bark area of the stem was occupied by D.brevicomis. Such trees are probably the rule where the infestation is heavy and aggressive.

The top half of tree K101 was evidently killed by a 1926 late fall attack of Ips confusus, D.monticolae and D.brevicomis. The balance of the trunk was attacked by D.brevicomis in the spring of 1927, resulting in the death of the tree.

Trees K105 and TJK110 were also topkilled in 1926, by I.confusus and D.brevicomis and completely killed by D.brevicomis in the spring of 1927.

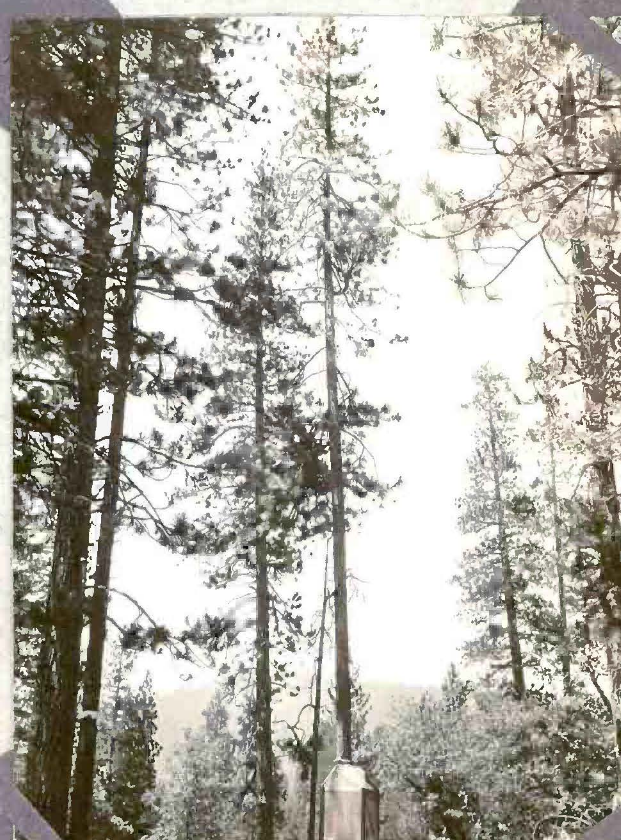
Tree KPA-1 was killed in 1927 by a combined attack of D.brevicomis, D.monticolae and Melanophila gentilis. The tree was actually killed by the D.brevicomis attack although D.monticolae attacked in the top before D.brevicomis attacked farther down.

While a great many more insect killed trees were analyzed in this way, the above is sufficient to indicate the complexity of the infestation in an area. It also shows how impossible it is to judge the total infestation of a species in an area without falling or climbing every tree, for it is evident from Fig. 4 that with the same loss in volume and number of trees the actual amount of infestation of a species could vary within wide limits.

Photo 1.
Showing crown of
Tree K1-I in center.

Photo 2.
Base of Tree K1-I
after removal of cage.

Photo 3 - K8.
Tree K8-I showing thin
straggling crown and
upper half of cage.



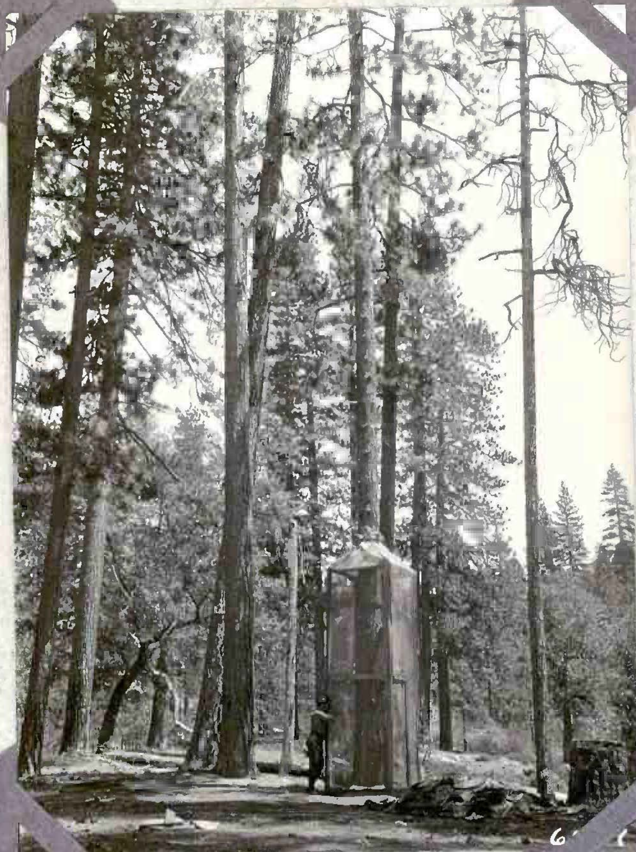


Photo 4.
Caged base of Tree K27-I.

Photo 5. Base of K1-II caged with 20 foot cage. Note canvass floor used to prevent loss of beetles in the ground, also the D.b. infested bark piled around the trunk.

Photo 6.
Showing crown of K1-II.

Photo 7.
New type of cage on tree K4-II. Beetles being introduced through hole in screen which is ten plugged with cotton.

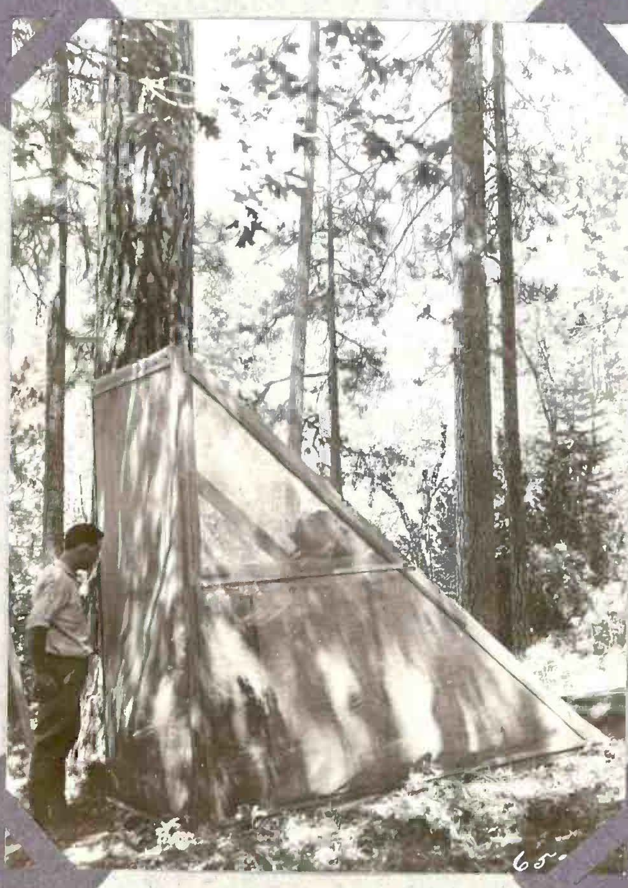


Photo 8.
Type of rearing cage used. Filled with D.b.infested bark.

Fig. 1.

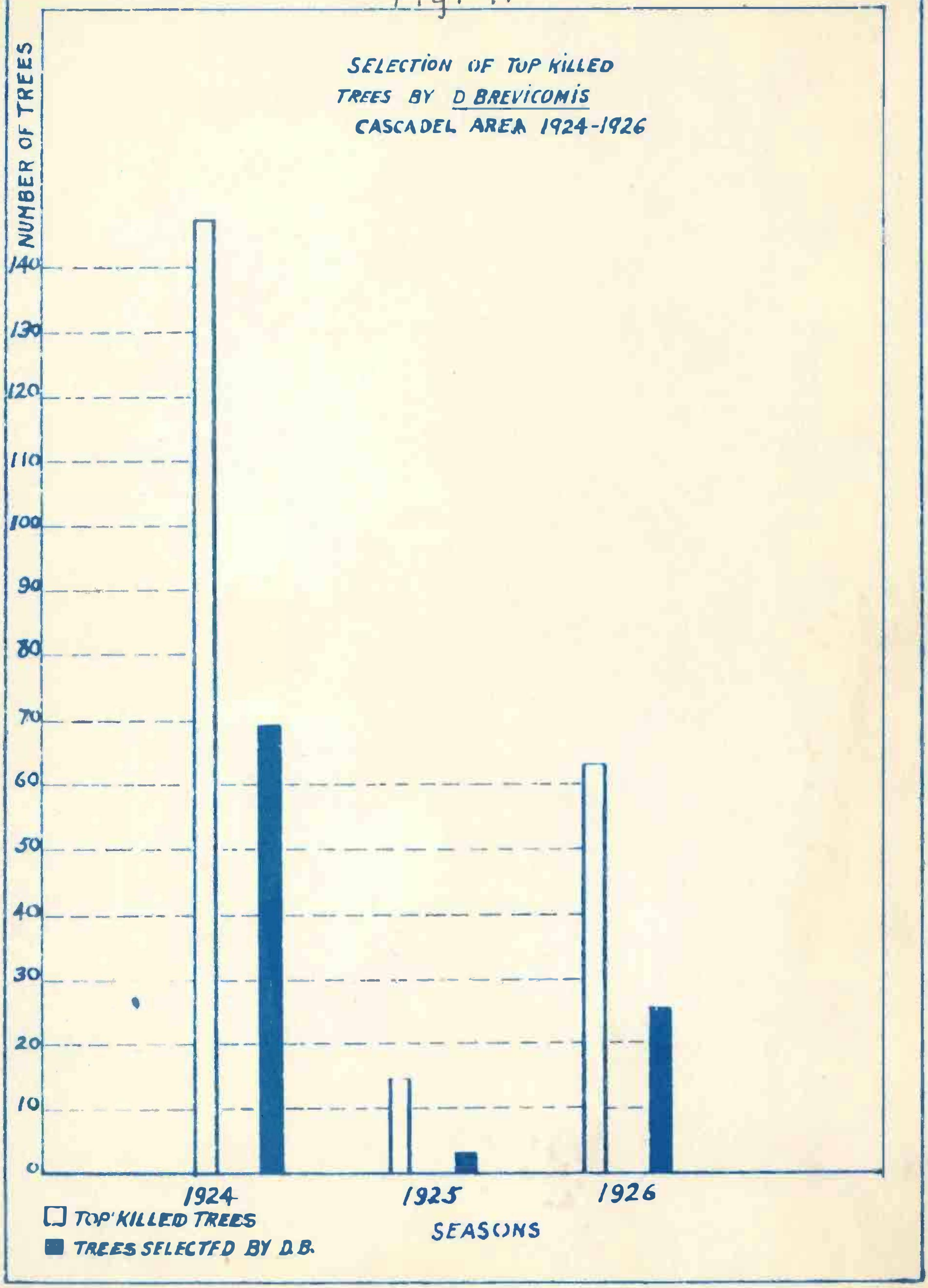
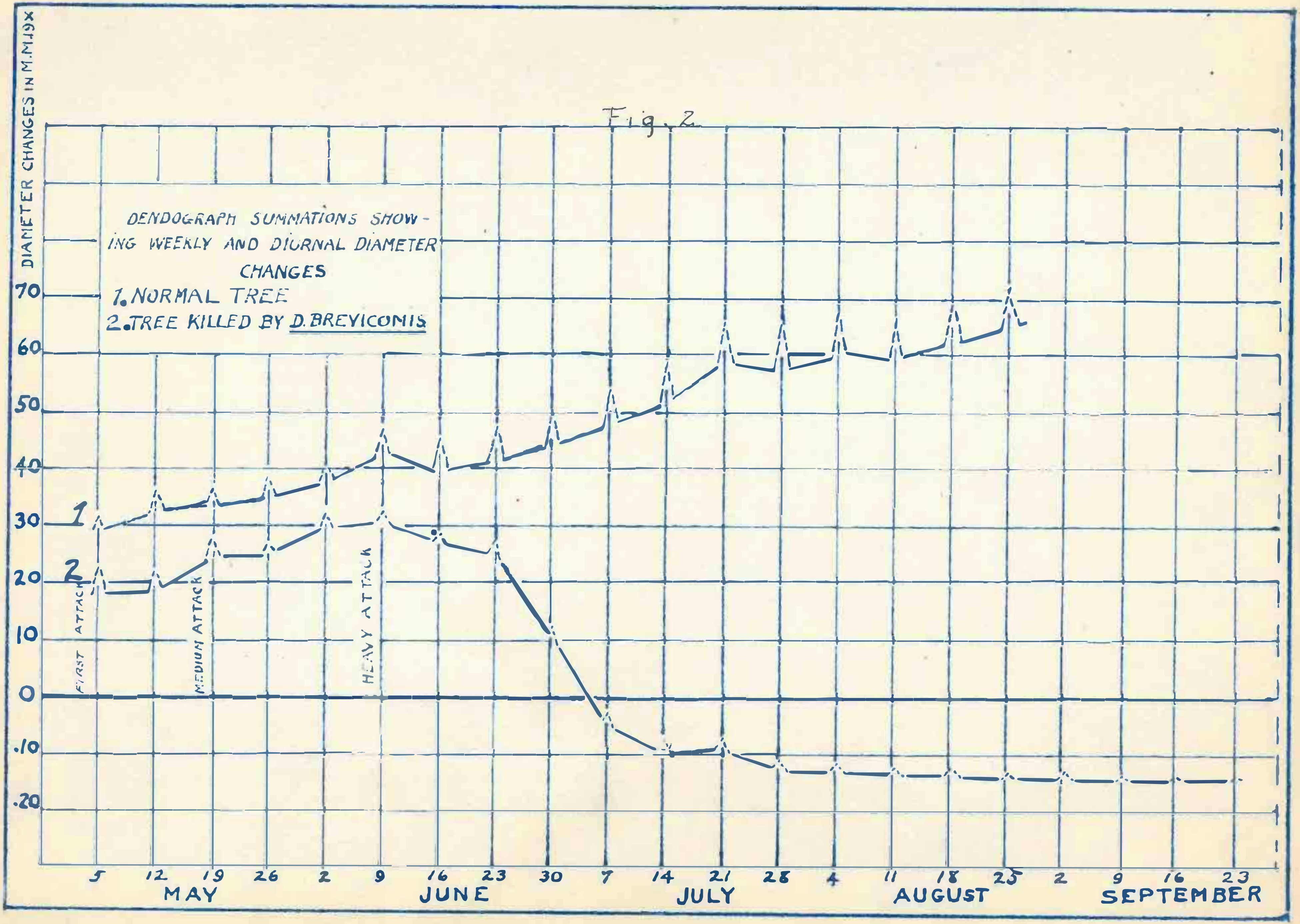

SELECTION OF TOP KILLED
TREES BY D BREVICOMIS
CASCADEL AREA 1924-1926
NUMBER OF TREES
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1924
1925
1926
TOP KILLED TREES
TREES SELECTED BY D.B.
SEASONS

Fig. 2



DIAMETER CHANGES IN M.M.19X
DENDOGRAPH SUMMATIONS SHOWING WEEKLY AND DIURNAL DIAMETER CHANGES
1. NORMAL TREE
2. TREE KILLED BY D. BREVICOMIS
70
60
50
40
30
20
10
0
.10
.20
1
2
FIRST ATTACK
MEDIUM ATTACK
HEAVY ATTACK
5
12
19
26
2
9
16
23
30
7
14
21
28
4
11
18
25
2
9
16
23
MAY
JUNE
JULY
AUGUST
SEPTEMBER

Fig. 3

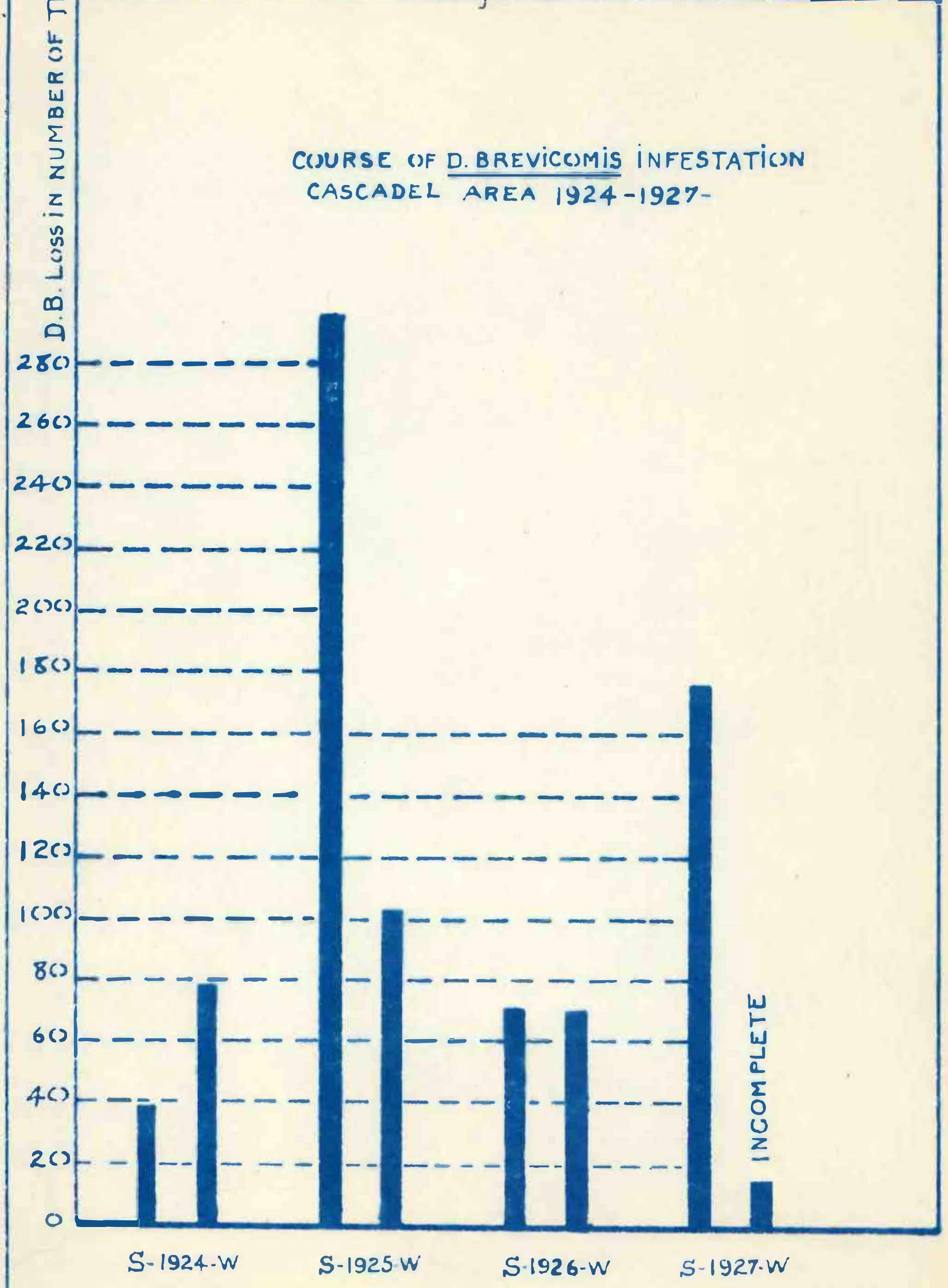

COURSE OF D. BREVICOMIS INFESTATION
CASCADEL AREA 1924-1927-
D.B. LOSS IN NUMBER OF TREES
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
INCOMPLETE
S-1924-W
S-1925-W
S-1926-W
S-1927-W

Fig. 4 - Stem Analysis Showing Distribution of Insects in Western Yellow Pine Killed by <u>D. brevicomis.</u>